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A TUNGSTEN COMPARISON LAMP IN THE PHOTOMETRY OF CARBON LAMPS.

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In the photometry of incandescent lamps the substitution method is commonly used. That is, the lamp measured is not compared directly with a standard, but with a "comparison lamp" which is carefully calibrated against a candlepower standard or standards at the beginning of a run, and at frequent intervals. This method is adopted not only to obtain the greater accuracy of a substitution method, but to avoid operating a valuable standard continuously, with consequent comparatively rapid change in its value. After the standard check, the results of the measurement depend entirely upon the correctness and constancy of the comparison lamp. Since, however, the comparison lamp is subject to the changes inherent in the type of filament, it is necessary with carbon lamps to use only seasoned ones, and to keep close watch on their candlepower by checking with standards.

Some time ago, Professor Rosa, who is in charge of the photometric work of the Bureau, requested us to try a Tungsten lamp, operated at voltages to give carbon lamp colors, as a comparison lamp in the testing of carbon filament lamps. The object in view was to obtain a long-lived and constant comparison light which at the same time would give perfect color match with all types of carbon lamps. It was expected that this would be found the case with the Tungsten lamp, because, first, the candlepower changes with this filament are small during life, even at rated voltage; secondly, the life of all glow lamps is greatly increased at high watts per candle, and the Tungsten lamp matches the carbon lamps in color at efficiencies near 3 watts per

mean horizontal candle, or two and one-half times the normal rating of 1.25 watts per candle. If the relationship holding between watts per candle and life for carbon lamps is approximately true for the Tungsten as well, this means an increase in life of at least twenty times. Consequently the qualities of longevity and constancy could be predicted. The further advantage of color match is of great importance where accurate photometric work is required. Concordant readings by different observers can not be expected where a color difference exists in the lights measured. In the Bureau's commercial work, separate standards for 3.5 watts per mean horizontal candlepower, and 3.1 watts per candle are used. The values of these are the means of readings made against the primary 4-watt standards by all the members of the photometric section. With lamps of each efficiency, the appropriate standards and appropriate comparison lamp color are used. In this way the color difference difficulty is eliminated, except in the preparation of the standards, where it is met by securing once for all the mean and most probable value obtainable. Since the Tungsten lamp at low voltages will match either 2.5, 3.1, 3.5, or 4 watts-per-candle color it lends itself well to this plan.

Two months' experience with the Tungsten comparison lamp has shown it to fully equal expectations, and to be much superior for the purpose to carbon lamps.

The details of installation are here given as a guide to any who may desire to duplicate the arrangement. An 80-watt, 120-volt lamp was taken, and the voltages determined experimentally, at which it gave the same color as 4, 3.5, 3.1, and 2.5 (Gem) watts-per-candle lamps. These voltages were 79, 84, 87, and 97, respectively, corresponding approximately to 4.5, 3.7, 3.4 and 2.6 watts per mean spherical candle. Obviously the candlepower varied greatly for these different voltages. With a candlepower scale, as used on the Bureau of Standards commercial photometer, it is necessary to have the comparison lamp accurately 16 candlepower. A means to accomplish this with the Tungsten lamp was imperative, and was found in the use of diaphragms, since the candlepower of the 80-watt lamp at all colors was greater than 16. It was impossible to place the diaphragms

before the lamp itself since the distance of the diaphragm from the center of radiation, due to the size of the bulb, would permit an error of 3 per cent in the candlepower readings at the ends of the scale. Two means of overcoming this difficulty presented themselves. First, an image of the filament could be formed by a lens or concave mirror, and the image diaphragmed. Secondly, a ground-glass screen could be placed in front of the lamp, and the diaphragms placed over this. The latter plan was adopted as most convenient, although it was then necessary to back the lamp with a mirror to secure sufficient light. With a larger lamp the mirror would be unnecessary. Lamp, mirror, and ground-glass screen were mounted together on a stand, the ground glass being held in a groove wide enough to receive the several diaphragms which cut down the light to very closely 16 candlepower for each color. These diaphragms vary from 2 to 3.5 inches square, and are all small enough so that the error due to considering the glass surface as a point source is negligible.

In order to set the lamp to give exactly 16 candlepower, the same procedure was adopted as in the Bureau's work with carbon lamps. The voltage is adjusted by trial (or by knowledge from previous work) to give very nearly the correct candlepower reading. Then a number of standards are read, and from the mean deviation of the readings from the standards' true values the change in voltage which will give the correct reading is calculated. For carbon lamps (3.5 watts per candle) the percentage change is given by the relation $\left(\frac{V_2}{V_1}\right)^{5.6} = \frac{cp_2}{cp_1}$, or in the differential form, $5.6\ dV = d(cp)$. In order to follow the same plan with the Tungsten lamp, it was necessary to know the voltage-candlepower relation at the efficiencies used. This was obtained from data given by Mr. F. E. Cady,[1] from which it follows that from 2.6 to 4.5 watts per mean spherical candle the voltage exponent ranges from 3.8 to 4; the relationship to use is therefore 3.9 $dV = d(cp)$. By the use of this relation (actual numerical values are kept tabulated on the photometer table) the comparison voltage is accurately fixed.

[1] Transactions Illuminating Engineering Society, October, 1908.

Because of the comparatively low voltage of the Tungsten lamp it has been found convenient to place in series with it an adjustable rheostat, and measure voltage across the two. In this way, by placing stops on the rheostat corresponding to 3.1, 3.5, etc., the comparison voltage is made uniformly 100 volts, or some other convenient voltage if desired. For instance, with a run of 110-volt lamps, the voltage of each side of the photometer can be 110, and may be checked without moving from the same potentiometer post.

The Tungsten comparison lamp has proved eminently convenient and practical, and after two months' daily running of from four to seven hours, chiefly at 3.5 and 3.1 colors, the voltage to give 16 candlepower has changed less than two-tenths of 1 per cent.

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